Recovery of Radioactive Objects by Channel-Specific Analysis of Gamma Scan Data

Hunters Point Naval Shipyard, San Francisco, CA

Presented By

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Objective

- Present a methodology to locate buried radioactive objects (ROs) below ground surface

Overview

- Site Location and Background
- Problem and Challenge
- Channel-Specific Gamma Scan Data Collection and Analysis
- Assessment of Results
- Summary

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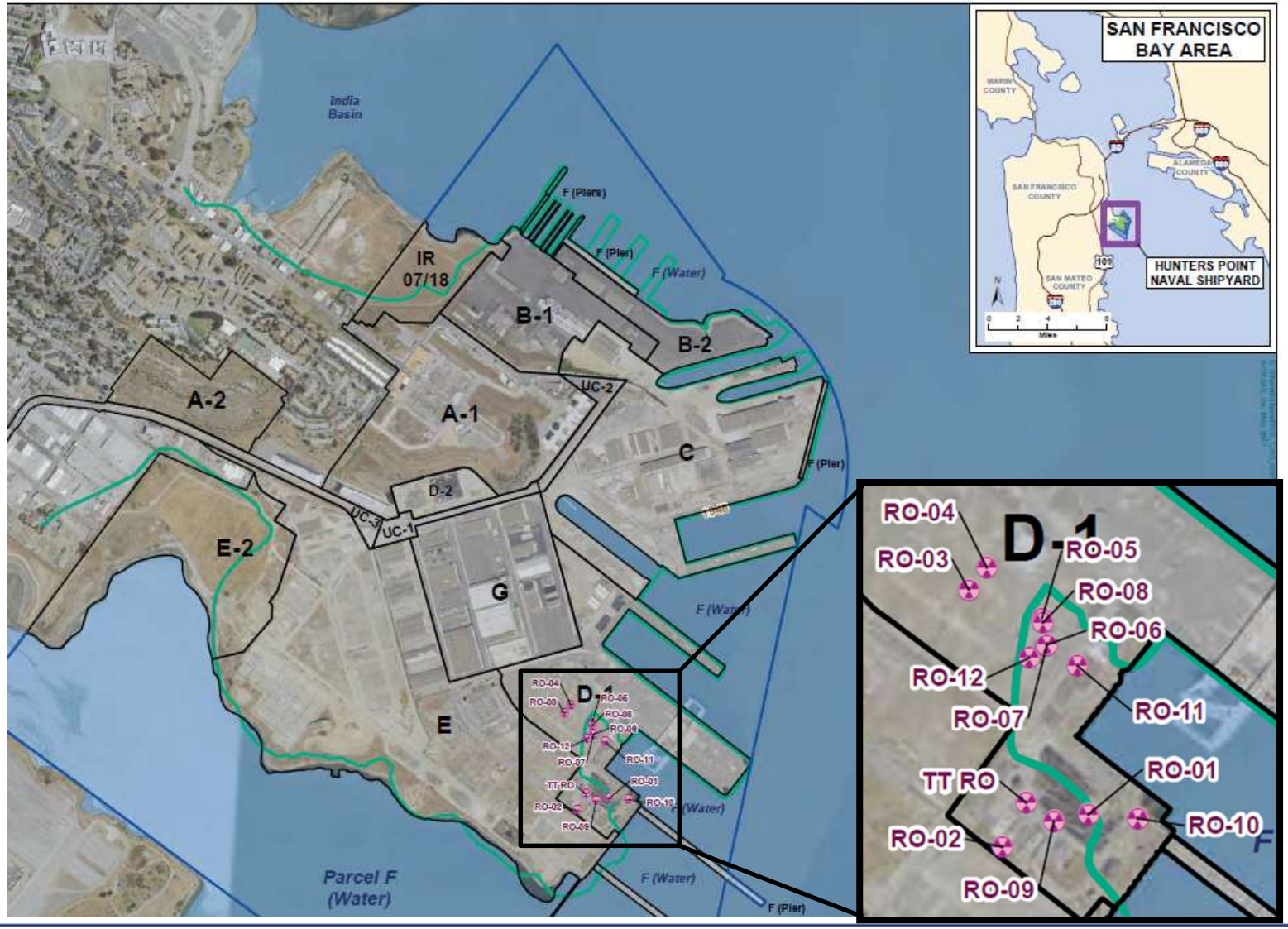
Parcel D-1



Mobile Gamma Scan Technique

Common Features:

- Uses Radiation Solutions, Inc. RS-700 mobile gamma-ray detection system
- Detector mounted on cart pulled behind small tractor with adjustable throttle

RS-700 Gamma-Ray Detection System

Enhanced Data Quality

- Fixed (surveyor-independent) scan rate / source-to-detector geometry
- High gamma sensitivity (large NaI crystal)
- Gamma energy discrimination capability

Regions of Interest

Gamma count data analyzed by regions of interest (ROIs)

- RS-700 collects photon energy response over 1,024 channels
- Each radionuclide has a specific energy peak per IAEA
- The channel-to energy conversion (1 channel= ~3keV)

- Background ROIs (e.g., K-40, Cs-137, Ra-226, Th-232)
  - Naturally occurring (or environmentally present) serve as *de facto* background baselines
- Project-specific ROIs
  - Based on radionuclides of concern (or gamma-emitting progeny)

Selected ROIs Used in Analysis

ROIs are programmed into RS-700 prior to data collection

ROI	ROI Name	Channel		Energy (keV)		Basis/Discussion
		Start	End	Start	End	
02	K-40	457	523	1371	1569	based on K-40 1461 keV peak (IAEA setting)
03	Ra-226 (1764)	553	620	1659	1860	based on progeny Bi-214 1764 keV peak (IAEA setting)
04	Th-232	803	937	2409	2811	based on progeny Tl-208 2614 keV peak (IAEA setting)
06	Ra-226 (609)	182	222	546	666	based on progeny Bi-214 609 keV peak
07	Cs-137	183	247	549	741	based on Cs/Ba-137 662 keV peak
10	Gross Counts	1	1024	3	3072	Based on full channel (i.e., total gamma) spectrum

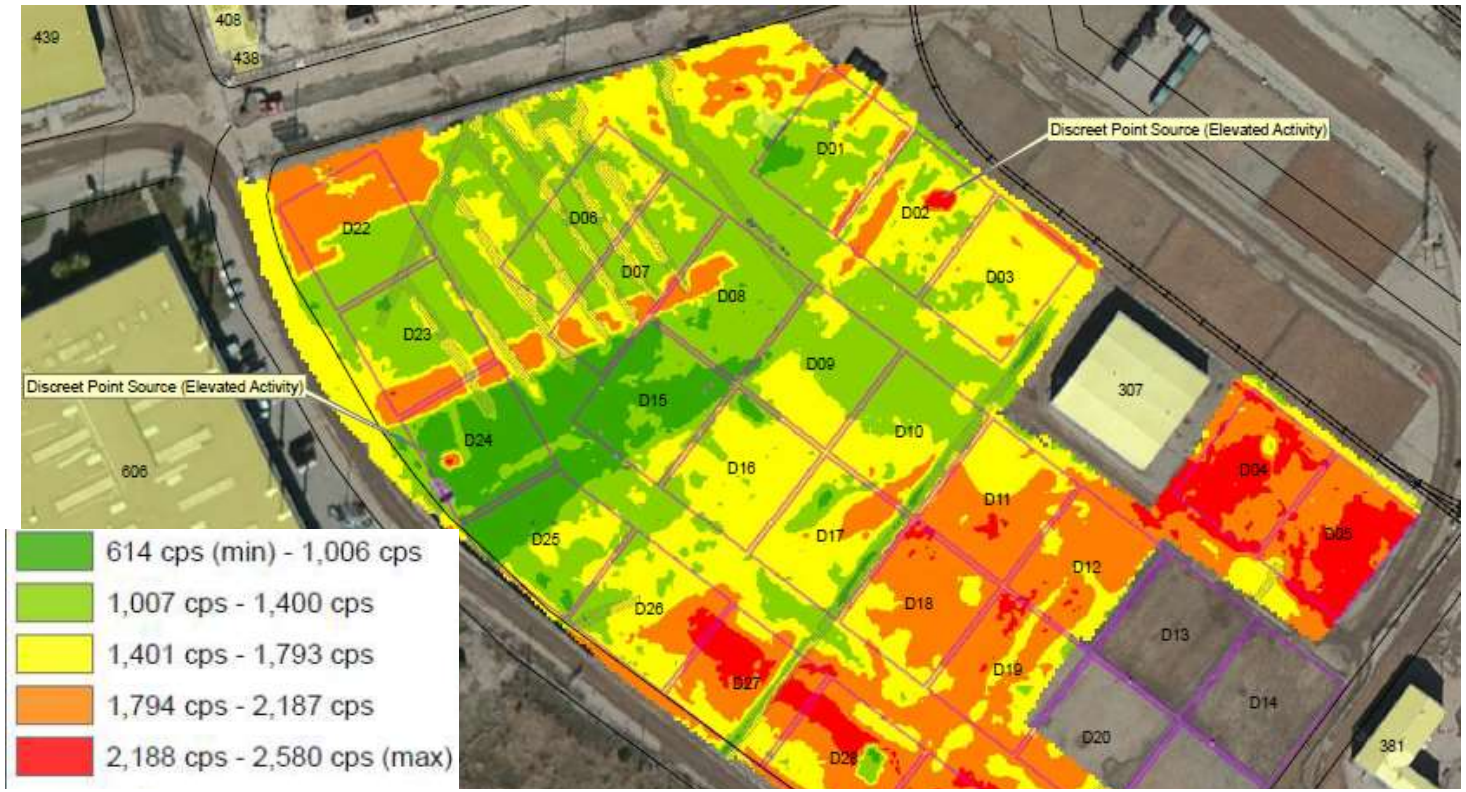
Channel-Specific Analysis Using ROIs

Step 1 – Assess data population using background ROIs

- spatial distribution of fill materials and/or variation in naturally occurring radioactivity in soil
- broken out for analysis into radiologically homogeneous areas

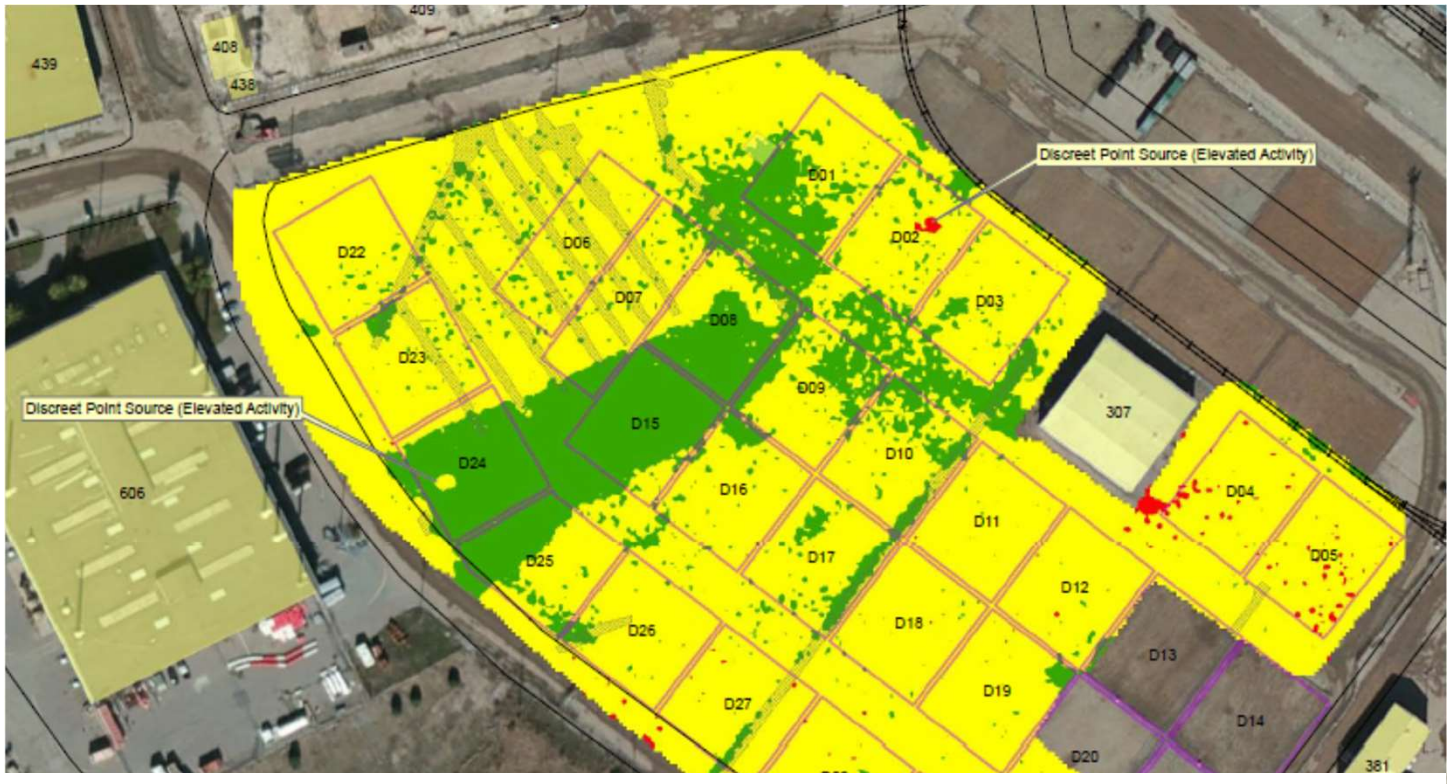
- The following slides illustrate the Step 1 process

Gross Counts [ROI 10]



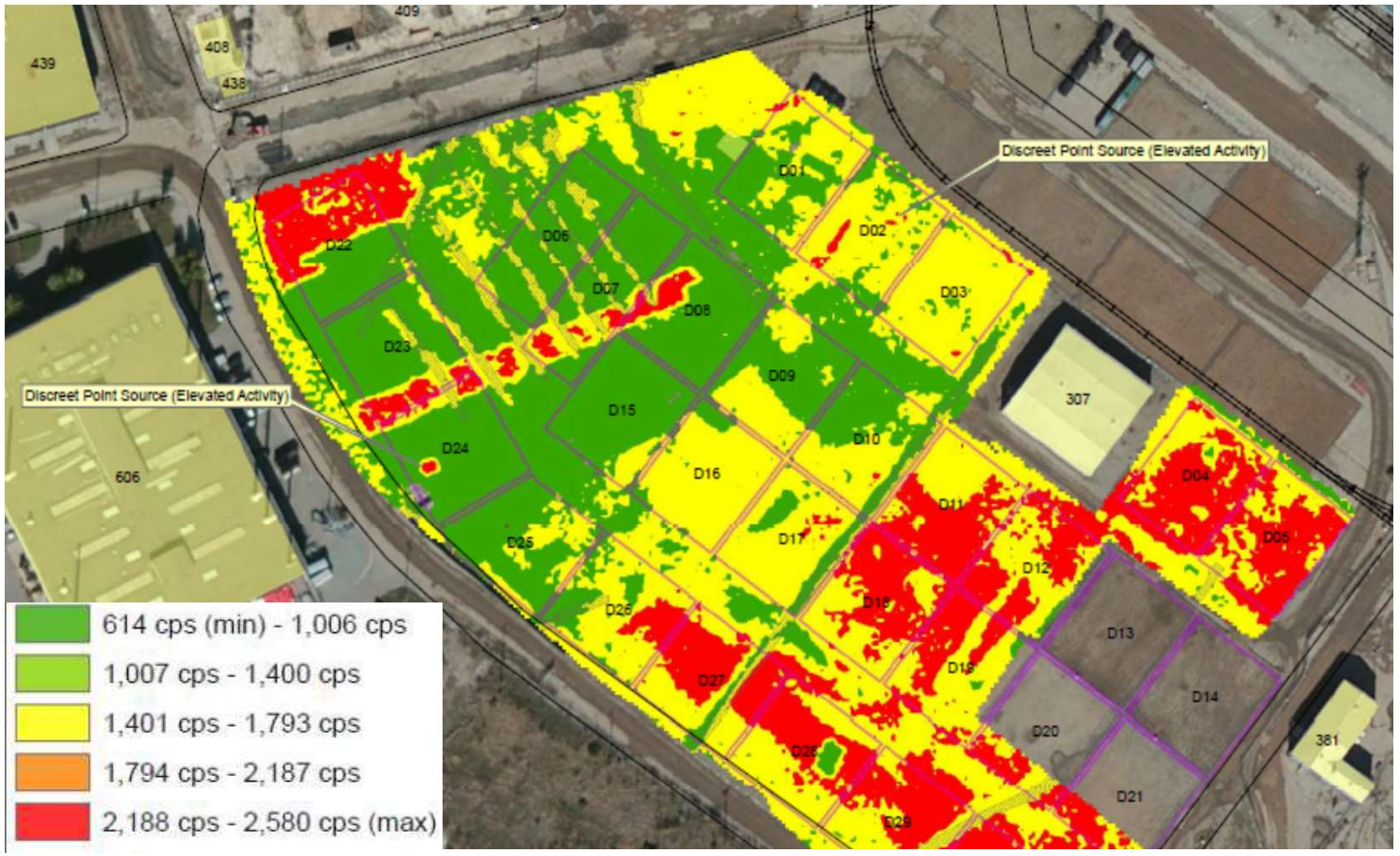
- Bottom half is clearly dissimilar to top half of site
- Geometric shapes suggest event-related dissimilarities
- Red clusters in top right and middle left are clear outliers
- Most spatial analyses of data do not proceed past this point

Th-232 (2614 keV) [ROI 04]



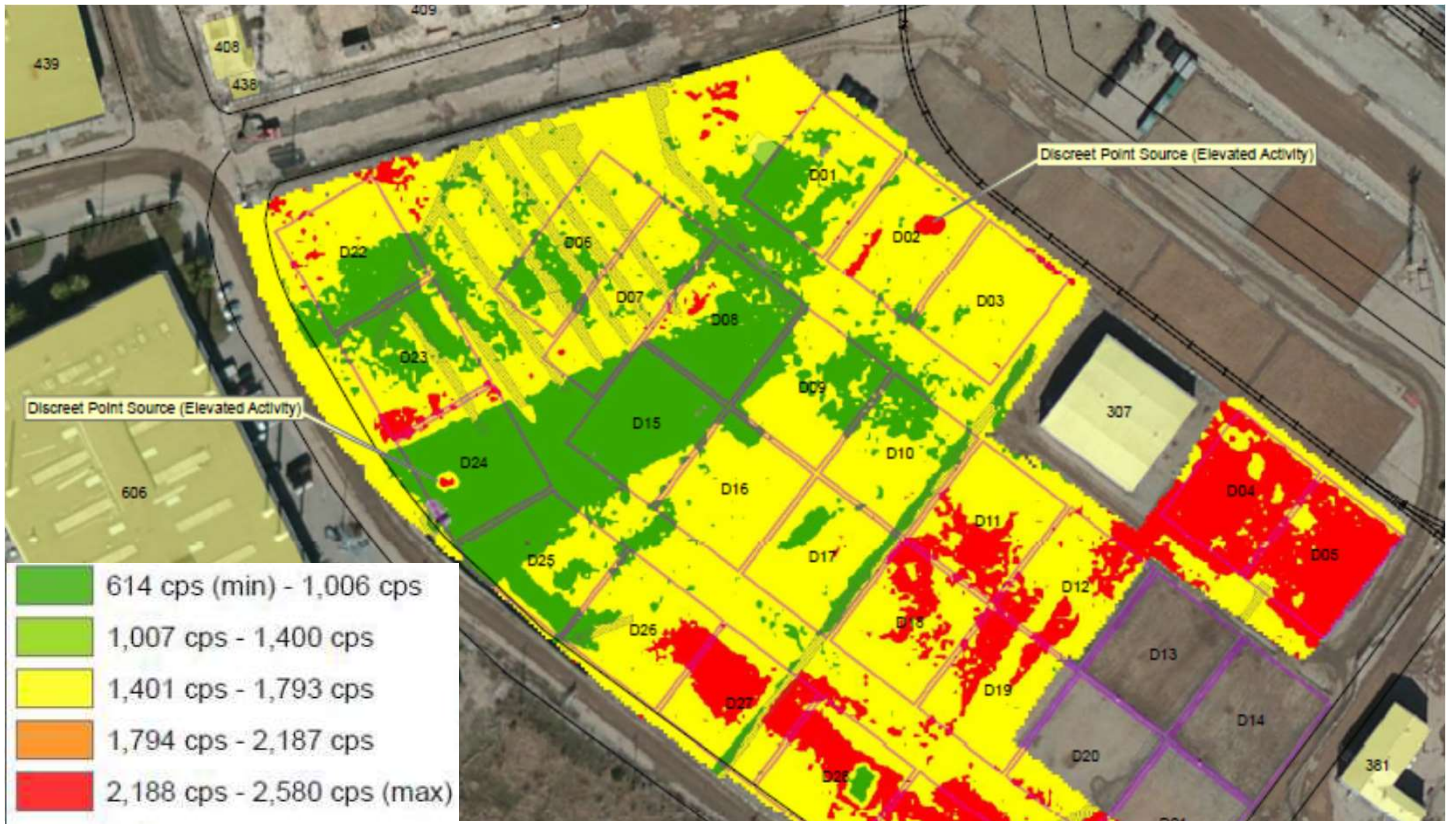
- Due to its relatively high energy region, ROI is least affected by presence of other naturally occurring radionuclides
- Largely similar soil concentrations across entire site
- Red clusters in top and middle right areas distinctly apparent (but not of particular interest at this point in analysis)

K-40 (1461 keV) [ROI 02]



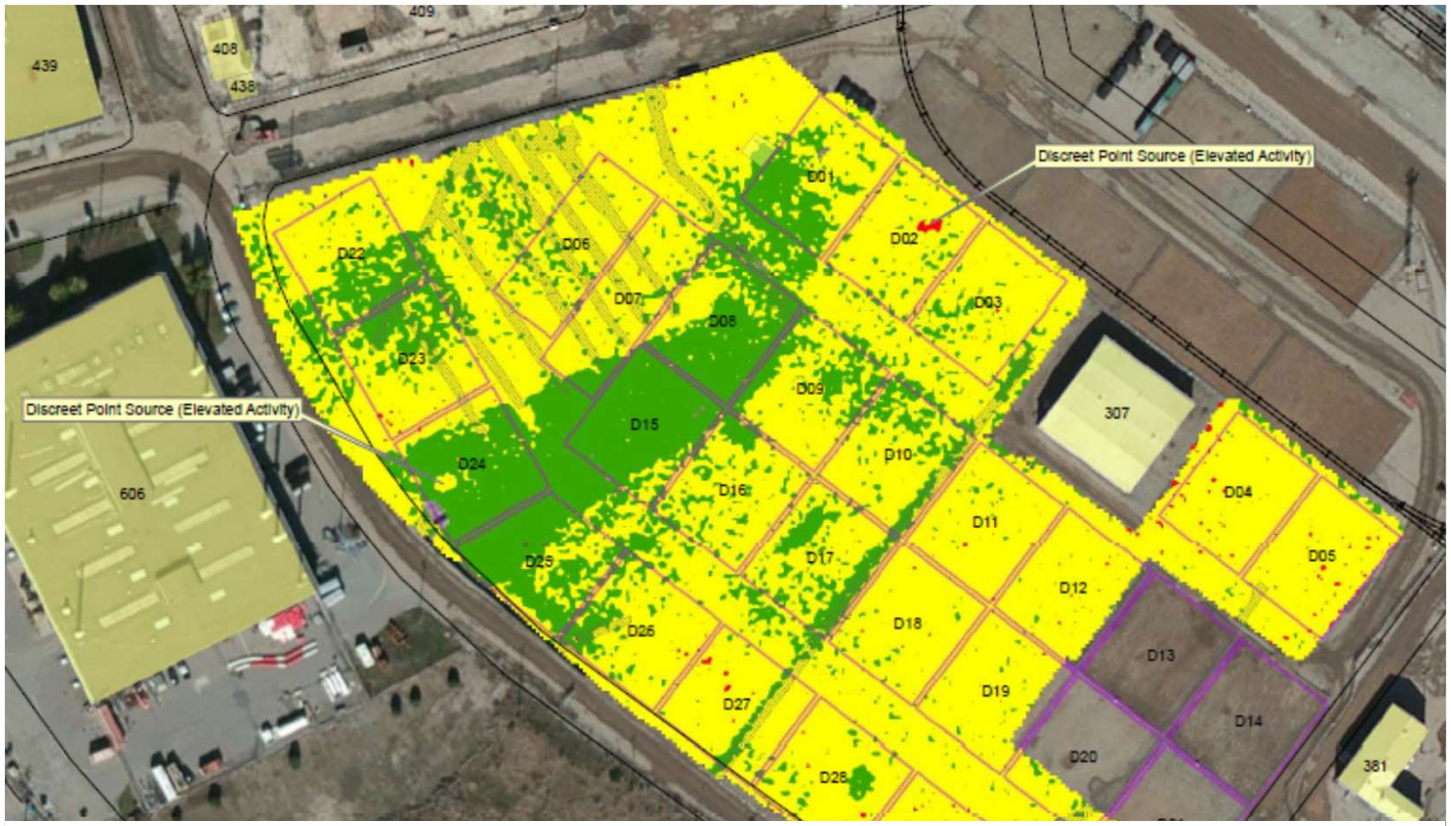
- Due to its relatively high energy region, ROI is largely unaffected by presence of other naturally occurring radionuclides
- Distinctly dissimilar soil areas in top corner and bottom half of site

Cs-137 (662 keV) [ROI 07]



- Limited utility as ROI since it largely overlaps much of same region as Ra-226 (609 keV) ROI
- Distinctly dissimilar soil areas in top (vs bottom) half of site, also evident on K-40 ROI map

Ra-226 (1764 keV) [ROI 03]



- Red oval cluster in top right and smaller clusters located in lower right apparent on both Ra-226 ROI maps
- Clusters could indicate borrow material picked up and laid down in systematic manner or discrete Ra-226 objects

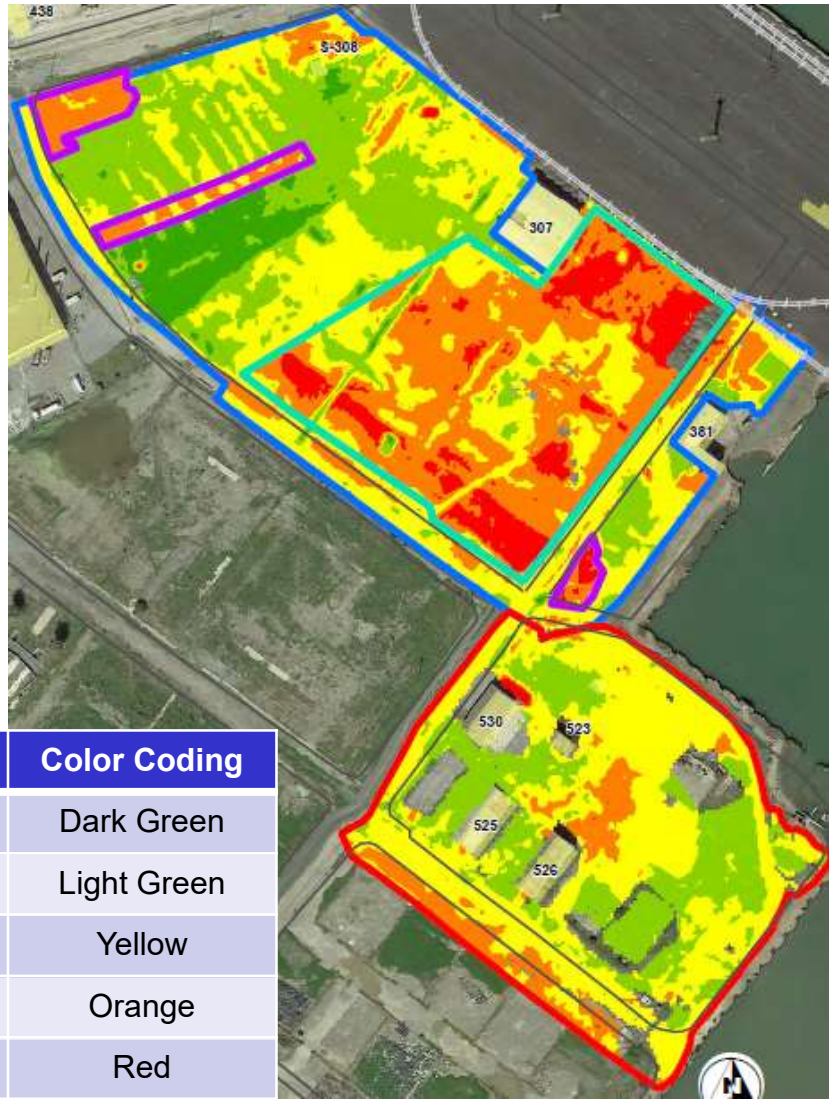
Channel-Specific Analysis Using ROIs

Step 2 – Spatially segregate data population into like groupings for more detailed analysis

- Allows drill-down to extract more detailed information from data
- More detailed data analysis performed using project-specific ROIs to pinpoint discrete radiation anomalies that may warrant field investigation
- Graphical and numerical methods used to focus investigation on areas which cannot be explained using ROI-based analytical methods
- Statistical outliers become focus of analysis

Radiologically Similar Subgroupings

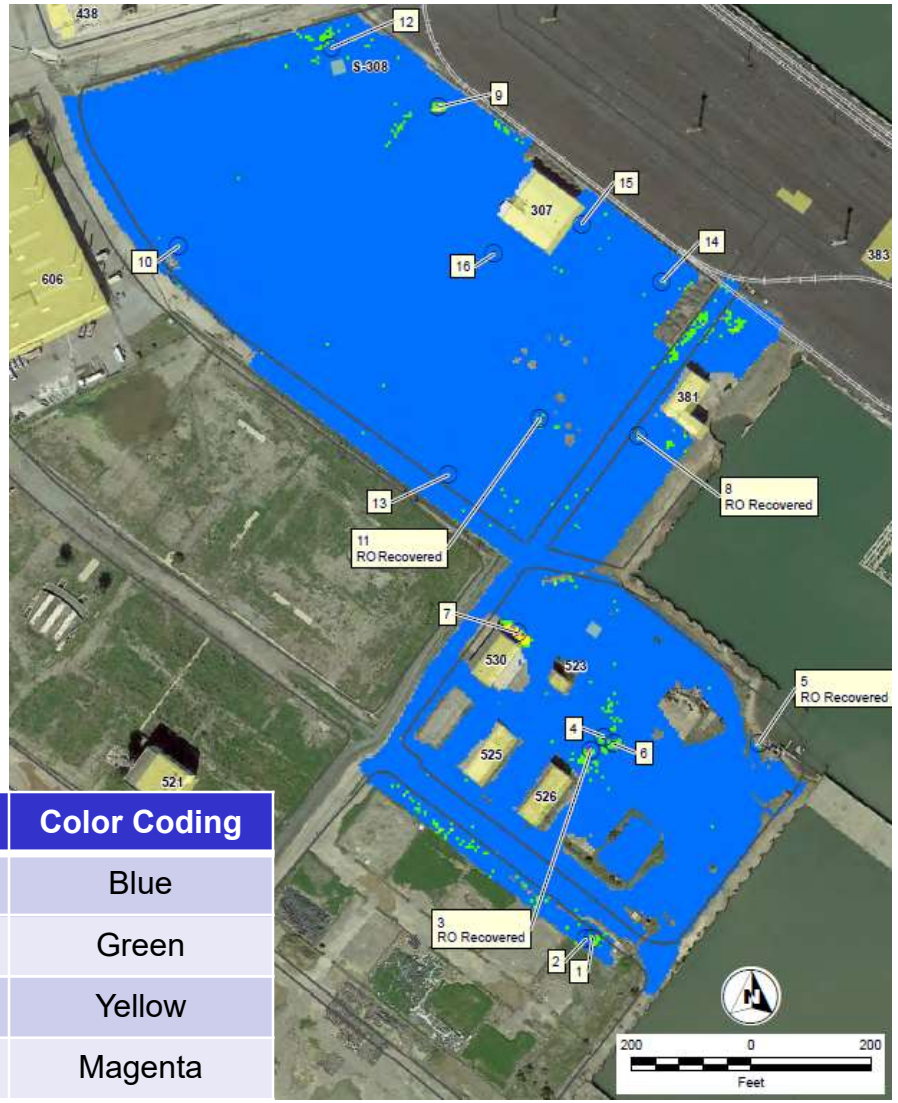
- Graphic shows gross counts [ROI 10] over entire Parcel D-1 area surveyed
- Data population spatially broken out into four radiologically homogenous subgroupings for further analysis
- Each corresponding data set used to generate z-score contour maps to assess spatial patterns in data and finite locations that may represent discrete objects
- Focus shifts from spatial groupings to statistical outliers that may represent radioactive objects



Gross Counts	Color Coding
< 20%	Dark Green
> 20% and < 40%	Light Green
> 40% and < 60%	Yellow
> 60% and < 80%	Orange
> 80%	Red

Z-Score Contour Mapping

- Separate z-score maps generated for each subgrouping
- Separate contour maps graphically joined together as a single map to identify discrete field locations to investigate
- Four color divisions used to represent z-score value ranges
- Extreme spatial dissimilarities largely disappear when analyzed by subgrouping
- Sixteen discrete locations selected for field investigation; four objects recovered



Z-Score	Color Coding
< 2.0	Blue
> 2.0 and < 3.0	Green
> 3.0 and < 4.0	Yellow
> 4.0	Magenta

Assessment of Results

- Radioactive objects recovered at depths between 1 to 3 ft bgs with radiation levels as low as 25 µR/hr on-contact
- Recovered objects demonstrate how channel-specific analysis enables discovery of objects with lower radioactivity at greater depths

ID	On-Contact Reading (µR/hr)	Recovery Depth (ft bgs)	Description of Radioactive Object
01	3,200	0.5	Button or deck marker
02	23	0.5	Small soil clump with visible rust particles
05	1,500	0.5	1½-in piece with clip on one side
06	480	1.5	Small soil clump with visible rust particles
07	60	1.5	Small soil clump with visible rust particles
08	500	2-3	Corroded and damaged can
09	460	2-3	Corroded/damaged metal gauge or can
10	420	2-3	Small soil clump with visible rust particles
11	25	1-2	Small soil clump with visible rust particles
12	33	1-2	Small soil clump with visible rust particles

Objects recovered using channel-specific analysis

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Summary

Improved Data Collection Technique

- Fixed (surveyor-independent) scan rate / source-to-detector geometry
- Significantly higher gamma sensitivity based on size of NaI crystal
- Gamma energy discrimination capability (programmed ROIs)

Channel-Specific Analysis of Gamma Scan Data

- Use of background ROIs (e.g., K-40, Cs-137, and Th-232) to spatially segregate radiologically homogenous groupings for further analysis
- Use of project-specific ROIs to distinguish between naturally occurring radionuclides and to identify most likely locations of discrete objects
- Graphical and numerical methods used to further focus on areas which cannot be explained using ROI-based analytical methods

Knowledge Check

Which of the following is not a benefit of the RS-700 system?

A. ability to detect lower amounts of radioactivity present
B. ability to distinguish between different radionuclides in the field
C. portability
D. ability to play back collected data for analysis at a later date

Contacts and Questions

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Questions ?